Argonne National Laboratory's Integrated Water Resource Management (AIWRM) Working Group

Mission and Capabilities

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ABSTRACT

Argonne National Laboratory (ANL) is offering extensive capabilities in the area of **Integrated Water Resource Management (IWRM)** capacity building, related professional training, and infrastructure development. **Argonne's Integrated Water Resource Management (AIWRM) Working Group** is leading projects in the area of IWRM. ANL's IWRM projects are primarily aimed at alleviating water shortages in water-deficient regions and countries around the world, especially in the developing world. This is accomplished through projects targeting water and related energy infrastructures using techniques such as, saline water desalination (both brackish water and seawater), industrial wastewater reclamation and recycling, groundwater assessment, relevant policy and regulatory issues, and related energy needs. Detailed description of AIWRM Working Group's capabilities and experience is given here, including several examples of past IWRM-related projects carried out by Argonne's expert teams. By coordinating the expertise and efforts of water and energy experts across the Lab, AIWRM Working Group is able to offer basic and advanced training workshops for water specialists, transfer appropriate technology and know-how, and help the client to implement the acquired knowledge in the field.

1. Background

Water shortages, unreliable water supplies, and poor water quality have in recent years been considered as major obstacles to sustainable development and poverty alleviation that require urgent attention. The United Nations estimates that global water withdrawals amount to some 10-20% of total renewable water sources. Water supplies, however, are very unequally distributed and cannot cost-effectively be moved long distances. About 40% of the world population lives in river basins with less than 2000 cubic meter of water per person per year for all purposes (a rough estimate by the UN below which water shortages may be experienced), and over 1 billion people lack access to safe drinking water. In such areas, water shortages are increasingly limiting development options. It is predicted that by 2025, about half of the world's population – some 3.5 billion people – will live in areas facing serious water shortages.

In recent years, momentum has been building calling for the creation and implementation of national and regional **Integrated Water Resource Management (IWRM)** plans to address these pressing water problems. The IWRM approach is designed to address a nation's or a region's key water-related sustainability problems (i.e., water for drinking purposes, health, food, energy, and environment) more effectively and efficiently. The change in moving from fragmented to integrated approaches to water problems is a challenging one and requires fundamental changes in policy making, technology and infrastructure, and finances. One vital element of such a plan is ***capacity building***. Examples for capacity building steps and actions include strengthening the technical expertise of a nation's or a region's water managers; training water managers, scientists, and engineers in modern water capacity building techniques (e.g., water purification and reclamation, brackish and seawater desalination, efficient water use, and energy for water and water for energy issues); developing relevant databases and data modeling tools for effective future IWRM planning and implementation.

No generic blueprint currently exists to the approach a country or region should take in developing an IWRM plan. Such an effort is multi-disciplinary in nature and requires intense and constant collaboration between the various stakeholders and experts developing such a plan. Following a declaration made at the World Summit on Sustainable Development (WSSD) held in Johannesburg in 2002 that called on nations to "develop integrated water resource management and water efficiency plans by 2005, with support to developing countries," the Global Water Partnership (*www.gwpforum.org*) has concluded that authorities should be able to draft a detailed IWRM Plan in one year with continuous modifications to the plan as needed and to avert the grim predictions for 2025.

2. Argonne's IWRM Working Group

Mission Statement: **With water professionals around the world, and particularly in developing countries, lead the assessment of various water needs and related infrastructure requirements, planning, and training that are in the framework of**

broader Integrated Water Resource Management (IWRM) plan development and implementation efforts.

ANL, as a premier US Department of Energy (DOE) science and engineering national lab, is well positioned in taking a leading role in helping developing countries, particularly through the process of capacity building, achieve their own individually tailored IWRM plans. Indeed, several divisions within ANL (e.g., Decision and Information Sciences, Environmental Assessment, Environmental Research, and Nuclear Engineering) have active water-related projects that include projects related to river basin management, groundwater management, desalination, energy requirements and planning (including cogeneration of water and power), detailed hydropower evaluation, water policy and regulatory issues, and computer modeling and data assessment. Argonne is also home to a well established and recognized international training center and other proven international training capabilities and programs. Experts from the various divisions make up Argonne's IWRM (AIWRM) working group.

The AIWRM team's individual proven capabilities are grouped into four main categories:

- General water modeling and data analysis:
    - Groundwater and surface water modeling for site disposal activities;
    - Analyses of flow patterns, behavior, and quality for water basins, including dams;
    - Satellite, remote sensing and isotopic techniques for watershed analyses;
    - Numerical modeling and simulation of groundwater systems;
    - Groundwater and aquifer assessment and development using unique well drilling methods.

- Capacity building in water desalination and wastewater treatment and reclamation:
    - Planning, design of, and training in water desalination and wastewater treatment and recycling;
    - Unique software tools for economic analyses of cogeneration plants (desalination and power);
    - Energy calculations and assessment for coupled energy/water systems;
    - Integrated water resource management planning and education.

- Energy planning and analysis:
    - Market supply and demand analyses using Argonne computer models and tools;

  - Energy and power technology assessment and implementation;
  - Energy for water assessment and planning;
  - Interdependent relationships between water and energy.

- Water resources management regulatory and policy issues:
  - National and region-specific policy making including environmental considerations.

In addition to these four major categories, the Argonne team also has experience in developing and applying methodologies for estimating the costs of developing the infrastructures required for water and energy production and distribution.

Through a concerted use of these capabilities Argonne can provide comprehensive IWRM services to local clients and around the globe. Argonne experts can readily organize training and workshops for relevant technology and knowledge transfer. International professionals can travel to ANL and be exposed to the state-of-the-art multimedia educational facilities combined with lectures and hands on practical exercises.

2.1. Detailed Capabilities

2.1.1. General water modeling and data analysis

ANL offers unique capabilities in developing and using models to help understand and manage water resources. These models involve all aspects of groundwater and surface water flow and transport. Particular emphasis is placed on the quantity of water available and its quality.

In the area of groundwater modeling, the Environmental Assessment Division (EAD) has made frequent use of models such as MODFLOW, MT3DMS, and SWIFT II to simulate time-dependent, multi-dimensional groundwater flow and contaminant transport in both porous and fractured media. Source-term analyses have been performed with such models as HELP, and analytical expressions have been developed for specific, short-term applications. One-dimensional analytical expressions have been developed to evaluate groundwater impacts from disposal activities for sites with known groundwater quality problems and complex hydrogeology that are not easily treated with numerical models. Groundwater fate and transport modeling has often been used in completing hydrological impact analyses for Environmental Impact Statements (EIS) for the DOE, the Department of Defense, and other sponsoring agencies.

Surface water analyses have involved estimating river flows, depths, and water quality with such models as the HEC model, Hydrologic Model Simulation Fortran (HSPF), and CORMIX. When necessary, analytical expressions have been developed for case-specific analyses. The results of this type of analysis are frequently used in EISs for the DOE. Examples of such work include numerical modeling performed for the Nakdong River Basin in the Republic of Korea, oil-spill analyses performed for the Alaska oil pipeline, and catchment modeling for the Upper Colorado River system.

The HSPF model was used to provide estimates of water flow and quality for the Nakdong River and its tributaries in the southern part of the Republic of Korea. The region modeled represents more than 30% of the area of South Korea. This model incorporated such information as land topography from satellite imagery, precipitation, evapotranspiration, overland flow and runoff, land use practices (e.g., feed lot operations, water diversions, and dam operations), groundwater interactions, population projections, and industrial activities. Output from the model consisted of predictions of water supply and quality (Biochemical Oxygen Demand [BOD], Chemical Oxygen Demand [COD] and Ph) for three regions of the Nakdong River Basin (Andong, Taegue, and Pusan) for the years 2000, 2005, and 2010. Output of the model was used by the Republic of Korea to develop basin management strategies that were designed to achieve river basin water supply and quality goals. As part of this project, ANL provided the model to the client and also trained its representatives in the use of the model for future applications.

For the Alaska Pipeline re-licensing EIS, impacts of oil spills for various postulated accident scenarios were calculated for rivers (e.g., Yukon, Tanana, Gulkana, and Tazlina), Prince William Sound, and the Gulf of Alaska. Spills to open water were evaluated using the GNOME model. Impacts to rivers were analyzed using analytical expressions developed for bounded flow systems.

Surface water modeling for the Upper Colorado River Basin is being performed for the Western Area Power Administration. Here, dam release volumes and schedules are being developed for a system of dams and diversions for major tributaries of the Colorado River. The dam releases are constrained by biological considerations for downstream endangered fish species and power marketing economics. A heavy reliance is placed on analytical solutions and numerical modeling with the Riverware@ system model.

Inherent and unique in all ANL's water resource modeling is a strong coupling to other disciplines. For example, ecology and economics are often linked in the required analyses. Ecological ties include endangered species, wetland viability, and environmental indicators (water quality, temperature, flow, depth, etc.). Economic ties are often associated with dam releases, schedules, and power generation.

In addition, ANL has extensive experience in employing multidisciplinary technologies to address complex environmental problems related to characterization and restoration of contaminated vadose zone, groundwater, and surface-water systems. Methodologies have been developed by experts in the Applied Geosciences and Environmental Management Section (AGEM) of the Environmental Research Division (ERD) to facilitate an integrated, streamlined process for site characterization and watershed-based hydrologic and hydrogeologic system analyses. Technologies that have been incorporated are:

- Rapid acquisition of subsurface geologic and hydrogeologic information using direct-push technology to identify lithlogy, water saturation, and hydrogeologic properties and to conduct soil and water sampling;

- Well installation monitoring utilizing both direct-push and conventional drilling methods. Long-term monitoring network systems are also designed and managed;

- Water well installation (drilling, completion, and development) and design;

- Acquisition and application of geochemical and isotope data for analysis of multi-aquifer systems, identification of preferential flow, and determination of areas of recharge to groundwater systems;

- Employment of advanced techniques to estimate hydrologic properties of complex aquifer systems;

- Application of geophysical methods to identify 3-D lithologic (bedrock, aquifer, etc.) distribution as well as stratigraphic and structural relationships;

- Visualization of 3-D geologic strata and structures and aquifer systems;

- Simulation of groundwater systems using numerical modeling to optimize water resource management, to predict future contaminant migration, to evaluate restoration alternatives for contaminated aquifer systems, and to optimize remedial design;

- Integrated simulation of groundwater and surface water systems on a watershed-scale as a means to protect the aquifer systems from contamination and to optimize sustainable usage of water resources;

- Utilization of satellite imagery and remote sensing information to identify parameters for analyses of hydrologic systems in watershed-based studies.

2.1.2. Capacity building in water desalination and wastewater treatment and reclamation

Argonne has several projects related to saline water desalination and wastewater reclamation for planning and future capacity building. These projects focus on arid and semi-arid regions of developing countries in Asia and Africa and are coordinated by water experts from Argonne's Nuclear Engineering Division (NED). New and exciting projects, for example, have been recently proposed by ANL to the US State Department is Asia and Western Africa. In these projects, NED and other ANL experts will assist water specialists in water-deficient developing countries, through large-scale technology transfer and training, in assessing seawater desalination and industrial wastewater reclamation opportunities for coastal regions. This type of projects are aimed both at capacity building and integrating these future new freshwater resources into a comprehensive IWRM plan for developing countries.

ANL-NED is also working closely with international organizations such as the International Atomic Energy Agency and other national labs in investigating and assessing future cogeneration of water and power needs in the US and around the world. These projects are mainly characterized by detailed economic feasibility studies of cogeneration options, which are based on various design concepts of water and power plant combinations.

The above work mainly involves:

- Technical design of desalination systems coupled to steam and electricity producing power plants.
- Economic assessment of various desalination plant/power plant coupling options.
- Assessment of general water needs and infrastructure as part of an integrated water resource management strategy.
- General analysis of balance of plant (BOP) designs (e.g., bottoming cycles) and the coupling of systems in terms of thermodynamic efficiency and availability.
- Economic and market analysis and its possible application to other sector analyses.

2.1.3. Energy Planning and Analysis

ANL has extensive experience in addressing complex energy and environmental issues of domestic, international, and multinational importance. Argonne's Decision and Information Sciences (DIS) division offers a unique three-pronged approach to its domestic and international clients by leveraging capabilities in (i) software development, (ii) consulting and software application, and (iii) mentoring, training, and capacity building. For over 25 years, Argonne's multi-disciplinary teams have collaborated with researchers and analysts in developing countries in the fields of energy, power, and environmental systems analysis. Since 1978, ANL has trained about 1,300 analysts from 87 countries in the analysis of strategic energy and environmental issues.

For the energy and water interface, ANL has access to a large set of analytical tools that cover the entire spectrum from macroeconomic analysis to energy and environmental risk analysis. Future water consumption levels for energy production can be projected by various ANL tools: power systems models forecast water needs for hydro and thermal power generation; energy systems tools estimate future water consumption for entire fuel cycles/energy systems. The operation of hydro power plants may be restricted based on downstream river flow constraints and ANL tools can be used to estimate the operational and economic impacts these limitations may have. Likewise, Argonne tools can estimate the optimal medium to long-term water allocation strategies among multiple users (power and non-power) within entire watersheds. After code modifications, ANL models will also be able to analyze the economic impacts of any potential water resource constraints for thermal power generation. Regarding energy for water, analysts can use Argonne models to investigate the short- and long-term economics of various power/water cogeneration technologies using detailed hourly power systems dispatch analysis tools as well as multi-year power system expansion models.

Generation and Transmission Maximization (GTMax) Model: GTMax is used extensively by power companies, electric utilities, system operators, and merchant companies around the world to address strategic issues, such as the value and benefit of hydropower, regional interconnections, power market studies, etc. With its detailed, unit-by-unit, representation of the thermal and hydropower generation system and its comprehensive modeling of the transmission system (hourly simulation, DC optimal power flow), the model tracks hourly costs, revenues, and profits for each generating unit for a week at a time. For the Western Area Power Administration and the Bureau of Reclamation, Argonne uses the model to study the economic impacts of constraining hydropower generation in the form of downstream environmental restrictions. Argonne used the model recently for the US Agency for International Development to analyze the potential benefits of hydropower in Southwestern Europe. With its ability to model dual-output plants, GTMax can be used for detailed economic analyses of power/water cogeneration technologies. In addition, with some modification, the availability of cooling water could be included as an operational constraint in the model to determine the location-specific economic impact of potential limitations in cooling water resources.

PC-VALORAGUA (Value of Water) Model: The objective of PC-VALORAGUA is to determine the optimal power generation strategy of mixed hydro-thermal electric power systems. The optimal operation strategy is obtained for the system as a whole, with an emphasis on detailed simulation and optimization of the hydro subsystem operation. PC-VALORAGUA can simulate the operation of all types of hydropower plants (run-of-river, weekly, monthly, seasonal, or multi-annual regulation), including pumped-storage plants and multipurpose hydro projects. The model calculates possible production of hydropower plants based on either a historical series of monthly water inflows or synthetic water inflows with associated probabilities of occurrence. The model works with the hydraulic network of a country (or region) and can determine the optimal operation of up to 50 reservoirs in as many as 18 hydro-cascades in a system. PC-VALORAGUA calculates the marginal value of water in reservoirs at all times of the year. The mathematical expectancy of the future value of water is the basis for deciding whether to use the water from the reservoirs now or to retain it for later use. Combined with other models, Argonne uses VALORAGUA for the Word Bank in a collaborative effort with the Nepal Electricity Authority that is intended to analyze long-term power system expansion issues in Nepal and the role that hydropower is expected to play. The project also includes modeling power trading with neighboring India. PC-VALORAGUA was also used to model the cascade operation of existing and future hydro power plants and multiple irrigation reservoirs on the located on the Indus River in Pakistan. In other studies, PC-VALORAGUA has been used to model the operation of hydro power plants on the Zambezi River in Zambia, as well as the operation of the hydro power systems in Macedonia, Romania, Turkey, Colombia, former Yugoslavia, and other countries.

Wien Automatic System Planning Package (WASP) Model: This widely used model analyzes generating system expansion options, primarily to determine the least costly expansion path for up to 30 years that will adequately meet the demand for electric power, subject to user-defined constraints. Probabilistic simulation is used to calculate the production costs and reliability parameters for numerous possible future system configurations, and a dynamic programming technique is used to determine an economically optimal expansion path for the electric power system under consideration. With funding from IAEA and USDOS and technical support from ANL, Egyptian analysts used WASP to determine the preferred power system expansion path. Argonne used the model to carry out numerous least-cost generating system expansion studies for utility systems in many countries. The WASP model is in use in over 70 countries.

Energy and Power Evaluation Program (ENPEP): ENPEP has been used for many years around the world to analyze strategic energy issues. In about 50 countries, the model is actively used by private and government analysts for energy planning purposes. The World Bank, Global Environment Facility, and other lending agencies regularly rely on ENPEP analyses in their project loan evaluation process. The latest version, *ENPEP for Windows-BALANCE*, uses a graphical user interface to simplify the construction of energy system configurations. The model uses a nonlinear equilibrium approach that matches the demand for energy with available resources and technologies. Its market-based simulation approach allows ENPEP-BALANCE to determine the response of various segments of the energy system to changes in energy prices and demand levels. ENPEP-BALANCE can be used to estimate current and future water consumption across the entire energy system. Analysts can also use the model to analyze power/water cogeneration issues and estimate the potential future energy requirements needed for desalination purposes. Sponsored by the IAEA and USDOS, Argonne has recently used the model in a joint study with researchers from 6 Mexican institutions to analyze long-term energy market projections for Mexico supplemented by forecasts of related atmospheric emissions of a number of carbon and non-carbon pollutants. For the World Bank, Argonne used ENPEP to investigate a number of carbon mitigation technologies and policies for Turkey. Hydropower generation plays a significant role in Turkey and had to be modeled in detail.

In summary, Argonne can provide the following services in energy planning and analysis:

- Forecasting electricity and energy demand as a driver for future energy-related water consumption;

- Hourly, short-term analysis of power systems operations under traditional or restructured market structures with detailed simulation of thermal and hydropower stations and their associated water consumption or water release;

- Medium-term optimal allocation of water resources among power and non-power uses;
- Long-term power generation expansion analysis identifying the role various thermal and hydropower technologies will play over up to 30 years;
- Long-term national energy and environmental projections and associated water consumption across all fuel cycles;
- Economic analysis of power/water cogeneration technologies with forecasts of potential energy requirements for water production and expected market penetration of this technology;
- Economic analysis of water conservation technologies for power generation with forecasts of potential market penetration of these technologies;
- Training and capacity building in power, energy, and environmental systems analysis;
- Evaluation of the impacts of new technologies on water and energy requirements;
- Evaluation of alternative sources such as mine-pool water, oil/gas well produced water, and coal-bed methane water for agricultural and industrial purposes;
- Development of “road maps” for the effective and efficient expansion of water and energy systems;
- Development of methodologies for estimating the cost of developing and/or expanding water and energy infrastructures.

2.1.4. Water resource management regulatory and policy issues

The development and implementation of water and environmental policy is a complex process that needs to be based on accurate data and objective analyses. Argonne’s EAD's multi-disciplinary staff integrate science, engineering, and law to provide this basis for a wide range of federal and state environmental policy development. Related analyses take many forms, including issue identification, option comparisons, technology feasibility studies, impact assessments, implementation guidance, and critical reviews. EAD skills in addressing complex problems has proven helpful to decision makers in evaluating policy issues related to water, energy, facility operations, and the environment.

Sponsors have used EAD analyses to help develop and implement both inter-agency and intra-agency policies and formulate and comply with federal and state environmental regulations. Over the past 25 years, EAD staff have examined many aspects of key environmental problems that the nation has faced. The results of their work have contributed to debates over the form and content of new regulatory concepts, to the acceptance and use of new technology, to the development of cost-effective regulatory requirements, and to the development of alternative ways to implement policies. Such sound policy and regulation formulation, tailored to specific environments and purposes, is essential to the development and implementation of an environment-friendly IWRM Plan.

3. Concluding Remarks

AIWRM Working Group is embarking on a renewed and concerted effort to aid water-deficient regions and countries in the around the globe in alleviating their oftentimes severe freshwater shortages. Through expert hands-on training, technology transfer, and field missions, AIWRM experts and others in Argonne can offer innovative solutions to challenging small and large scale water capacity building and related infrastructure projects. The AIWRM team is also tapping ANL's extensive experience in the area of energy and power infrastructure assessment and planning to offer training and guidance to the client in integrating it with the required energy-consuming water systems.

For further information and any inquiries please contact:

Dr. Ron S. Faibish, Chair, AIWRM Working Group
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL 60439
Tel: (630) 252-8355
Fax: (630) 252-6690
Email: rfaibish@anl.gov

AIWRM Working Group Members

Chair: Ron S. Faibish
Deputy Chair: Guenter Conzelmann
Joseph C. Braun
Richard R. Cirillo
Richard D. Doctor
John R. Gasper
Jerry L. Gillette
John R. Krummel
Lorraine M. LaFreniere
Mark C. Petri
David Tomasko
Yuejun Eugene Yan

Appendix: Sample Projects and Studies

I. Hydrological and Water Quality Models and Basin Management Strategies for the Nakdong River Basin

Argonne, together with several universities in Korea, participated in a study to develop management strategies for the Nakdong River Basin, the second largest river basin in the Republic of Korea. The study was initiated in 1997 by the Research Institute of Industrial Science and Technology (RIST) in Pohang, Korea. Argonne's role was to develop and apply a modeling framework to evaluate management strategies. Argonne reviewed data provided by RIST and developed a model to evaluate three scenarios for future basin management for the years 2001, 2006, and 2011.

Problem/Opportunity

The Nakdong River Basin has a drainage area of about 23,800 square kilometers and a population of about 7.2 million people. Moreover, its water resources also support an additional 6.1 million people living outside the basin. Rapid industrialization, land development, and population increases in the last few decades have caused a dramatic increase in demand for water from the river and have affected the water's quality. Although, its quality has, in general, been improving during the past decade, future development demands might reverse this trend. Appropriate management strategies are needed to ensure that water supplies are adequate and that water quality is appropriate for the intended use. To evaluate potential management strategies for the basin, a robust computer model capable of simulating a wide variety of complex physical, chemical, and biological processes is needed. Argonne was asked to develop such a model.

Approach

After evaluating several computer codes, Argonne selected the HSPF (Hydrological Simulation Program-FORTRAN) model for the study. HSPF was developed to evaluate basin-scale flow and water quality issues. Argonne used digital terrain elevation data to derive topographic aspects of the basin. The model was driven by time-series inputs for precipitation, climate variables, reservoir operations, consumptive water use, and pollution loadings for the period 1994 - 1995. The model was calibrated with flow data and with monthly measured data for concentrations of dissolved oxygen (DO), biochemical oxygen demand (BOD), nitrogen (N), and phosphorus (P) in Nakdong River water.

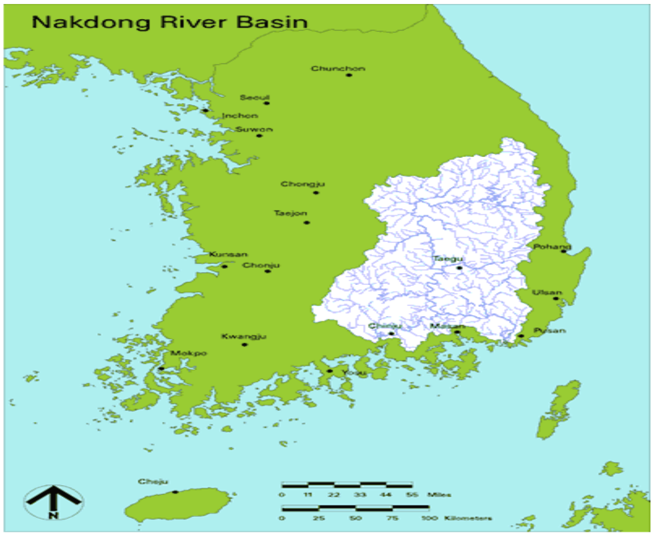
The calibrated HSPF model was used by RIST, with Argonne's assistance, to evaluate future scenarios affecting water quality. The future scenarios, evaluated for the years 2001, 2006, and 2011, included a "no action" scenario that assumes no additional domestic wastewater treatment facilities (Scenario 1), and two other scenarios that assume additions of domestic wastewater treatment facilities: one according to the 1996

Korean Ministry of Environment (MOE) Plan (Scenario 2) and the other according to the 1998 Revised MOE Plan (Scenario 3).

Results

The initial application of the model indicated the following results:

- The HSPF model developed for the Nakdong River Basin provided a useful tool for examining basinwide effects of various future scenarios.
- Model results for Scenarios 2 and 3 indicated that the mainstem water's quality improves primarily in the vicinity of the Kumho River, one of the major Nakdong tributaries where pollution loadings are highest and significant increases in domestic wastewater treatment capacity are planned.
- Additional water quality improvements in the Kumho River probably require flow augmentation as well as increased wastewater treatment.
- High levels of BOD, N, and P appear driven by non-point sources of pollution.
- BOD levels in the mainstem are heavily influenced by nutrient (N and P) levels. Both controls of non-point sources and tertiary treatment facilities for point sources of pollution are required to control BOD levels.
- Strategies are required to identify, manage, and reduce these pollution sources.
- Historical data indicate high coliform counts. This problem can be addressed only with strategies for improved domestic and animal waste management practices.
- Accurate flow data are needed for reliable evaluation of management strategies.
- Water quality data acquisition activities in the Nakdong River Basin should be planned in an integrated, basinwide manner related to specific management issues.



Nakdong River Basin, Korea

Future

The HSPF model developed in this project is the first "watershed" type model applied to the Nakdong River Basin. The model was initially run by RIST staff with Argonne's assistance, but it is currently being run independently in Korea to evaluate potential effects of other future scenarios, including the effects of the non-point sources of pollution identified in the initial application.

This project is a good example of a national laboratory developing a tool with an international partner and transferring the tool for implementation. This modeling tool will help Korean authorities solve water supply and water quality problems and reduce conflicts among different regions (in this case, upstream and downstream regions).

II. Visualizing Complex Watershed Interactions

Current laws and regulations require state and federal organizations to address environmental assessment and management issues at the watershed scale. New federal initiatives, such as those defined under the Clean Water Action Plan, indicate that integrated watershed studies, including restoration assessments, will become even more prevalent over the next five years. EAD is applying its experience and expertise to develop and use models, data, and other tools to help scientific teams, decision makers, and the public visualize complex watershed interactions.

Problem/Opportunity

Addressing environmental issues at the watershed scale has proven difficult. The complex spatial relationships among interacting parameters and variables are difficult to understand, which hinders agencies and stakeholders as they develop restoration strategies. Important watershed initiatives can get stalled in early stages of problem definition and strategy development. Many bottlenecks result from the inability of decision makers, the public, and the members of scientific teams to visualize the complex spatial phenomena. New tools are needed that can provide realistic 3-D visualizations tied to dynamic models and watershed data. The tools should be able to show the current state of the watershed and underlying interactions and be useful for developing restoration strategies that show desired future conditions based on alternative restoration strategies.

Approach

EAD is starting a project that will integrate watershed models, data, and visualization tools to give organizations a method of communicating complex watershed interactions to interested parties. Addressing watershed issues often involves difficult negotiations among stakeholders who define alternative strategies in nonquantitative terms. When alternative strategies can be visualized, negotiations can focus on core issues, and assessments are more likely to address these issues in a quantitative manner. Tools that integrate models, spatial data, and visualization techniques would provide interdisciplinary teams with a common focal point for problem development, definition, and approach.

EAD will use distributed parameter watershed models that are currently complete and have been accepted by the stakeholder community. Each watershed model will be coupled with a geographic information system (GIS) to create a model/GIS data system. Powerful 3-D rendering software that has recently become available allows specific model variables and parameters within a GIS to be photorealistically positioned in a 3-D landscape (the watershed). EAD will link this software to the model/GIS system to provide a quantitative, but visual, interface for model initialization, scenario development, and model output. Each parameter or variable will have a corresponding set of visual markers. Both historical (i.e., presettlement) and alternative future watershed landscapes will be visually portrayed. In addition, EAD has compiled a number of landscape indices that will be used to quantify landscape conditions.

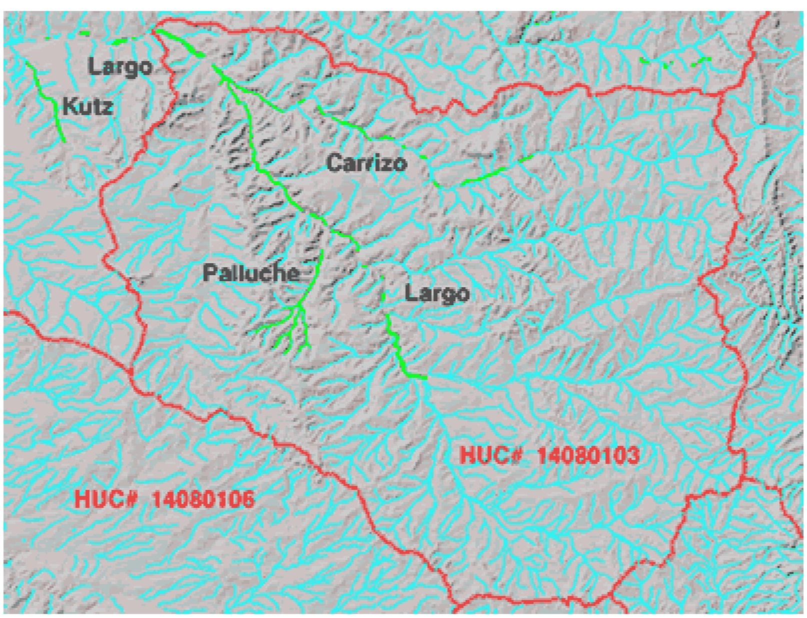
A key component of the initial effort will be developing partnerships with federal and state watershed managers and scientists who can help provide watershed data or develop specific issues. Partners who can help EAD locate a study watershed are also needed. The watershed cannot be larger than about 20,000 hectares, and, if possible, GIS database coverages (including detailed topography, land cover classifications, and soil classifications) for the area should be available.

Results

This project was started in December 1999. A partnership was established with Region 5 of the U.S. Environmental Protection Agency; the State of Wisconsin Department of Natural Resources, Watershed Restoration Division; and the Fox River 2000 organization. The Silver Creek Watershed will be used for prototype testing. Silver Creek is the primary drainage for Green Lake, the deepest inland lake and highest-priority watershed protection project in Wisconsin. Currently, EAD staff are processing the digital elevation files, developing model parameters, and using Landsat data to set the initial conditions for World Construction Set, the landscape visualization software that will be used for this project.

Future

By implementing this project in partnership with Wisconsin and the EPA, EAD will become a recognized participant in the expanding area of watershed restoration programs carried out at the state level. Feedback obtained from partners will give EAD an opportunity to develop an operational tool that can be used in other watershed projects.



Visual representations of riparian habitat areas in northern New Mexico, with shaded relief and U.S. Geologic Survey hydrologic unit watershed boundaries.

III. Role and Value of Hydropower Plants in Southeast Europe's Regional Electricity Market

Problem/Opportunity

Southeast Europe is moving rapidly toward the creation of a regional electricity market. Sponsored by the U.S. Agency for International Development (USAID), Argonne National Laboratory, in association with Montgomery Watson Harza, analyzed the role and value of hydro and pumped storage plants in this new regional electricity market. The analysis focused on the power market situation in 2005, which is, according to the Athens Memorandum of Understanding, the target year for the operation of the market for industrial and large, non-residential consumers.

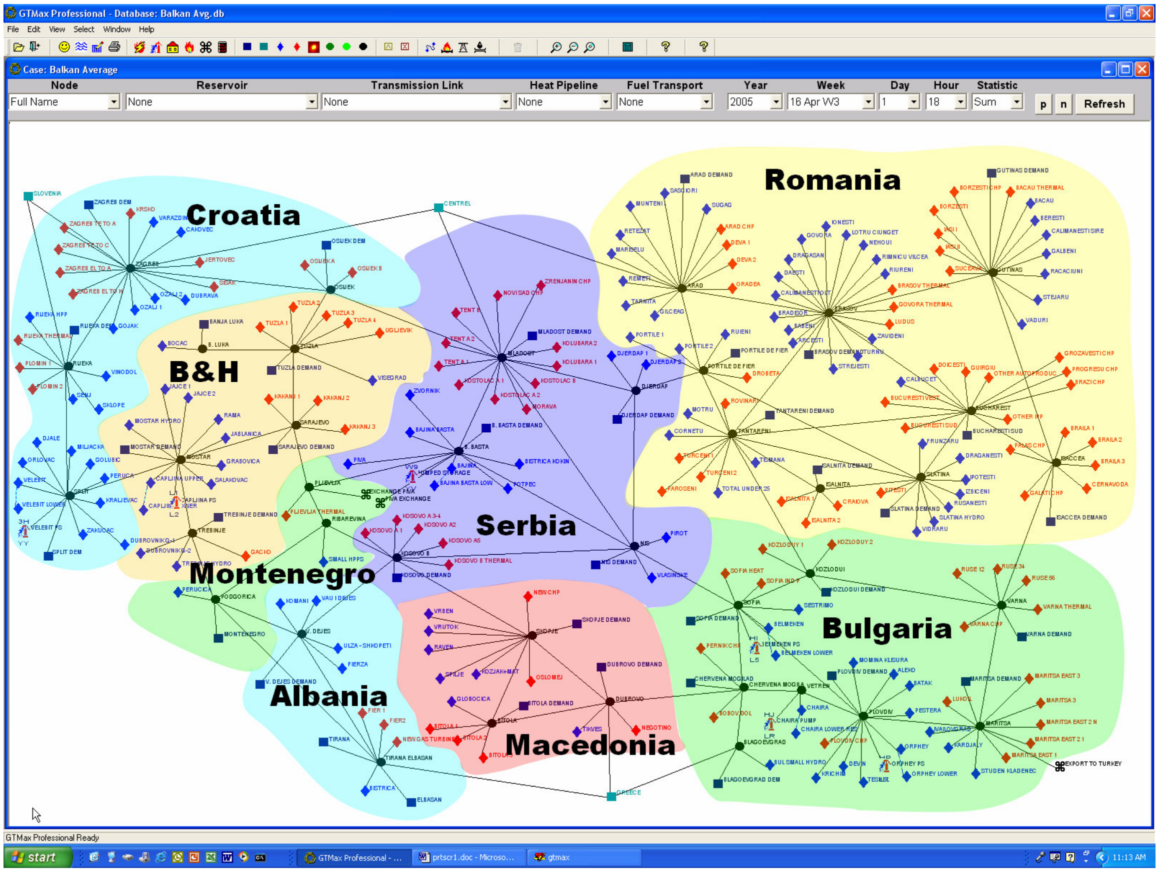
Approach

The study modeled the operation of electric power systems of seven countries in Southeast Europe and built upon previous studies performed by Argonne in the region. Included were electric utility systems of Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Macedonia, Romania, and Serbia and Montenegro. Turkey also participated in the project as an observer country but was not modeled. The analysis was performed using Argonne's Generation and Transmission Maximization Program (GTMax).

To estimate the role and value of hydropower plants in the regional electricity market, the GTMax analysis was performed for two sets of scenarios: (1) independent operation of individual electric power systems, and (2) integrated operation in the regional electricity market. The analysis was performed on an hourly basis for typical weeks in different seasons of the year (winter, spring, summer, and fall). To capture the variability of hydro inflows and their influence on hydro generation, the analysis was performed for three hydrological conditions: wet, average, and dry.

Results

The results obtained from the study confirmed that hydropower plants play an important role in Southeast Europe and would bring significant benefits to the development of a regional electricity market. The study also looked at the variability of water inflows in different countries of the region and found that there is more hydrological similarity than diversity. The typical pattern for most countries consists of very high inflows in spring and very low inflows in late summer. The study concluded that when the regional market starts operation, practically all of the countries can expect lower net energy supply costs. In general, a regional market operation would allow for more cost-effective electricity production in the region by increasing the utilization of the most economical generating units and better optimization of hydro and pumped-storage dispatch. The study also shows that, in a regional market operation, hydro and pumped-storage plants can provide an even greater amount of ancillary services than if the utility systems operate independently. The results obtained from the study are now being used for regional transmission planning studies to evaluate proposed investments into new transmission interconnections.



IV. Identification of Renewable Water Resources and Optimization of Water Usage Management in an Arid Region with an Integrated Approach

Problem/Opportunity

Egypt has a rapidly growing population; more than 60 million people are concentrated in less than 5% of the country's land area. Like other arid and semi-arid nations, Egypt requires the development of new agricultural lands to support its increasing population. Argonne, together with several universities in the US and Egypt, has been conducting a study to identify renewable water resources and to optimize water usage management in the western and eastern deserts of Egypt.

Approach

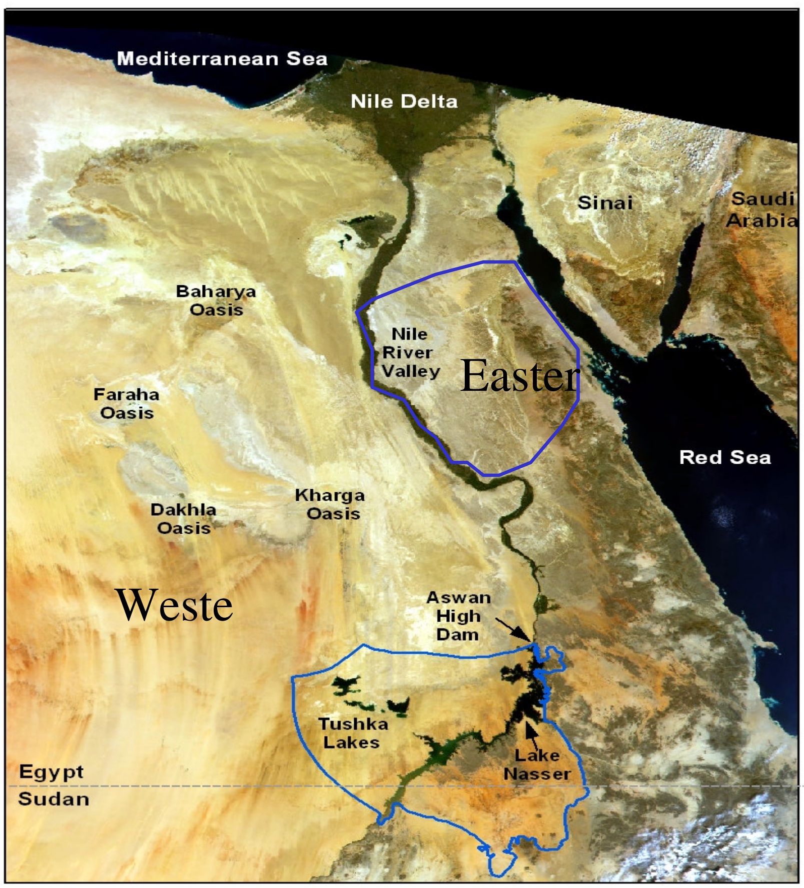
An integrated approach was developed to characterize hydrologic systems in the remote desert land. The study incorporated the following multidisciplinary technologies: (1) extracting DEM data (digital elevation data for ground surface) from the ASTER Earth Observation Satellite data, (2) identifying paleodrainage patterns by using the recently released shuttle-borne radar topographic (SRTM) data, (3) determining spatial-temporal changes of land use and land cover by integrating remote sensing data (TM, MSS, MODIS, CORONA) and digitized topographic and geologic information, (4) tracing sources of water, identifying the current and old recharge areas, and quantifying the mixing process between waters from different hydrologic systems by analyzing deuterium, oxygen-18, tritium, (5) age dating for waters and solutes by using tritium, C-14, Cl-36, Kr-81, tritium/helium-3, (6) constructing a hydrologic conceptual model using aquifer characterization methodology developed at ER, and (7) simulating interaction between hydrologic systems and developing sustainable water usage using numeric modeling. These technologies were transferred through training courses at Cairo University in Egypt.

Results

This ongoing study indicated the following:

- The study confirmed that water in the Nubian aquifer is fossil groundwater.
- In the area surrounding Lake Nasser (created with the installation of the Aswan High Dam in 1966), a dynamic interaction between lake water and Nubian groundwater was simulated. Two 10-year recharge periods were identified.
- During the two 10-year recharge periods, lake water provided a renewable source to the Nubian aquifer in the western desert.

- In the recent recharge period, excess water has been encroaching onto surrounding depressions, forming new lakes due to the gradual reduction of the hydraulic gradient between the lake stage and the groundwater level in the Nubian aquifer. The further development of new lakes (which would be identified by satellite data) could generate significant recharge of fresh water to fossil groundwater in the Nubian aquifer
- In the eastern-area desert, three hydrologic systems were characterized. The renewable water resources to the shallow alluvium aquifer were identified from water in Nubian aquifer (80%) and surface water infiltration (20%).
- Simulations for both hydrologic systems in the eastern and western deserts provided a quantitative basis for optimizing water usage management.
- The integrated approach provided a useful tool for characterizing hydrologic systems in a remote desert area.



V. Characterizing and Modeling the Impacted Upper Silver Creek Hydrologic System, Utah, Using a Watershed-Based, Integrated Approach

Problem/Opportunity

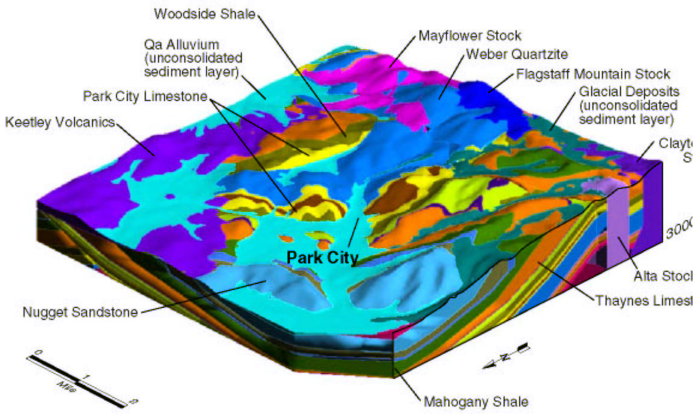
Watersheds are the basic units of land, surface water, and groundwater that integrate multiple processes. A better understanding of these processes and the impact of individual contaminated sites at a watershed scale has become increasingly important for managing water quality and water resources most cost effectively. This study demonstrates how to characterize watershed-scale hydrologic processes and reassess impact of multiple contaminated sites with respect to the watershed-scale processes using an integrated approach. The area studied was the Upper Silver Creek Watershed, Utah, a fast-growing area that was the site of 2002 Winter Olympics. The site has six active CERCLIS or NPL sites related to historical mining and tailing dumps, the primary contaminants of which are lead, arsenic, cadmium, and zinc.

Approach

The objectives of the study were: to characterize hydrologic systems at a watershed scale; to model hydrologic processes; and to reassess the impact of the four most contaminated sites on the watershed and set remediation priorities for decision making.

An integrated methodology was developed as follows:

1. Hydrologic system analysis and process modeling
2. Estimation of evapotranspiration with ASTER imagery (vegetation density and surface temperature)
3. Construction of a 3-D geologic model
    - Stratigraphic units
    - Structures (thrust and normal faults, anticlines, and synclines)



4. Construction of a hydrogeologic model
   - Hydrostratigraphic units
   - Distribution of hydraulic conductivities
   - Groundwater flow systems

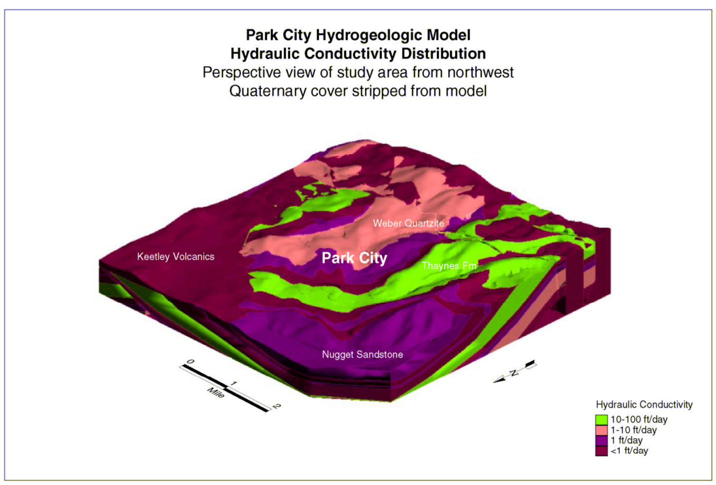


FIGURE 12. Silver Creek watershed – 3-D hydrology model without surficial deposits.

5. Construction of a surface water model
   - Channel flow (streams and mining tunnels)
   - Overland flow

6. Assessment of the impact of contaminated sites on the watershed

Conclusions

- A watershed-based, integrated approach improved understanding of hydrologic processes and the dynamic relationship between the subsystems.
- The results of watershed characterization and modeling provided bases by which to assess the impact of each contaminated site on hydrologic systems at the watershed scale.
- Impacts helpful in the development of remediation priorities and cost-effective water-quality management were identified.